UNIVERSITY OF ILLINOIS BULLETIN

Vol. V JULY 13, 1908 No. 34

[Entered Feb. 14, 1902, at Urbana, Ill., as second class matter under Act of Congress July 18, 1894]

BULLETIN NO. 25

LIGHTING COUNTRY HOMES BY PRIVATE ELECTRIC PLANTS

BY

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UNIVERSITY OF ILLINOIS
ENGINEERING EXPERIMENT STATION

URBANA, ILLINOIS
PUBLISHED BY THE UNIVERSITY

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Concerning Artificial Illumination

It is a fundamental principle of good artificial illumination to keep the illumination of objects as strong as is required for the uses to which they are put and to keep the intensity or brilliancy of the lights as low as possible. The first part of this principle can perhaps be readily appreciated by the average person, but the second part is directly opposed to his conception of how lighting ought to be done. It seems to him that to get good illumination a great brilliancy is required, and that anything that reduces the brilliancy of the light source tends to decrease the quality of the illumination. To understand this part of the principle it must be remembered first, that intensity or brilliancy of a light source, for example, an incandescent electric lamp, refers simply to the amount of light coming from each square inch of surface on the light-giving source, that is, the filament. If a diffusing globe is put about the lamp the filament itself is not seen and the light will appear to radiate from the entire surface of the globe. With a properly made globe the amount of light that is lost in passing through the glass is small so that the total amount of light given off will be almost the same as from the bare lamp. The amount of light per square inch of the surface, that is, the intensity, is much less than before since it now radiates from the entire surface of the globe instead of from the small filament. It must also be understood how the human eye acts under lights of different intensities. The eye, by means of an adjustable opening, called a pupil, endeavors to receive always a constant amount of light by contracting or dilating as the light is intense or dim. When the light reflected to the eye from any object is intense the pupil contracts so as to shut out a large part of the rays. When light of only low intensity reaches the eye from any body, the pupil opens wide so as to admit sufficient light to enable the eye to see the object distinctly.

Imagine a room illuminated by an unshaded 32 candle power lamp hung rather low, and that we wish to see clearly a book on a table near the lamp. To see the book, of course, some of the light must be reflected from it to the eye. Since it is close to the lamp the book receives considerable light and it would naturally be supposed that sufficient light from it would reach the eye to enable us to see it clearly. So it would if the eye were free to

adjust the opening of the pupil to the intensity of the light that is received from the book. However, since the low hanging lamp itself is almost in the direct line of vision the rays from it are also reaching the eye. These rays are so intense that the eye to protect itself must almost close the pupil. In doing so it also prevents sufficient light from the book from reaching the interior of the eye, so instead of seeing the book clearly we see it only indistinctly and at the same time have an unpleasant or even painful feeling caused by the forcible contraction of the pupil. Because we do not see the book comfortably we are erroneously led to assume that the light is insufficient.

Suppose we place over the lamp a diffusing globe, for instance, a round frosted globe. The intensity of the light is now cut down a great deal, but the total amount of light is not greatly decreased. Now when we attempt to see the book the rays of light which reach the eye from the lamp itself are much less intense than before. Hence the pupil is left more widely open, and even though less light is reaching the book than when the lamp was unshaded, the eye is enabled to receive more reflected light from it, and the book can be seen more clearly. Moreover, because the pupil is not so closely contracted, the eye feels much more comfortable, and the dazzling effect is much decreased.

Let us make one more change. Let us raise the lamp high enough so that the direct rays from it will not reach our eyes when we look at the book. Now as we have taken the lamp further from the book so that it receives less light than before, we will remove the round globe and replace it with a tulip or bell-shaped shade. This will deflect the light from the lamp downward so that the book will receive about the same amount of light as formerly. Now when we look at the book, there is no direct light from the lamp reaching the eye. Hence, the pupil can adjust itself to receive the proper amount of light from the book, and, since the book itself is receiving sufficient light from the lamp, the eye will receive enough reflected rays from it so that it can be seen clearly.

In our attempt to illuminate the book so that it could be seen clearly and comfortably, it will be noticed that our efforts have been directed, first, towards getting the light upon the book and second, towards diffusing the light, or towards keeping the light screened from the direct line of ordinary vision. These results

should be the end toward which all efforts in illumination are directed. They are obtained by the careful placing of the lights, and by the use of proper shades and globes.

Contrary to the popular idea, the selection of shades and globes should not be made primarily with regard to their decorative qualities. Properly designed and constructed shades and globes are made either to send the light in some desired direction, to diffuse the light, i. e., decrease its intensity, or to combine the two purposes. A person selecting a shade for a light should then bear in mind the location of the light, where the strongest illumination is desired, and whether the light needs to be diffused. A shade or globe should then be selected that will fulfill the required conditions. Many manufacturers will furnish diagrams showing how each particular shade or globe made by them diffuses and distributes the light. From these diagrams the proper selection can best be made.

Unquestionably the best shades and globes are those made from clear transparent glass similar to the Holophane globes. These have the inner surface of the glass given over to the flutings or prisms used solely for diffusing and softening the light. On the outer surface there are flutings calculated to deflect these diffused rays into directions where needed. Although the material is clear, transparent glass, the prisms and flutings diffuse and reflect the light perfectly while at the same time there is but small loss by absorption. These shades are designed in three classes according to the service that is required of them. One class (A) throws the strongest illumination directly downward, the second (B) gives a strong illumination in all directions below the horizontal, while the third (C) throws the strongest illumination slightly below the horizontal.

Opal, opaline and ground glass globes and shades give a well diffused light, but there is a considerable loss of light by absorption. The ground glass globes have the disadvantage of being difficult to keep clean. If properly shaped, these globes will throw the light in almost any desired direction.

The ordinary plain glass shades having fancy designs etched upon them, such as are supplied with many electric light fixtures, are of little value except for what little decorative qualities they may possess. They change the distribution of the light to only a slight extent and the amount of diffusion is almost negligible.

Opaque metal and silvered glass reflectors are very satisfactory for deflecting the light in any desired direction, but they give no diffusion and always make a room look dark and cold on account of furnishing no light to the ceiling. They also give too great contrasts between intense light and darkness so that the pupil of the eye, as one looks from place to place about the room, must continually contract and dilate so that it is soon fatigued.

Selection of Fixtures and Planning of Lighting Arrangement

Since the sole object of an electric light plant is to provide illumination for the house, it is common sense to plan a good lighting scheme and then build a plant and install wiring in accordance with this scheme. This statement is called forth by the fact that the opposite course is usually pursued. The wiring is usually installed and the outlets for the lighting fixtures placed in a sort of a haphazard way at any convenient spot. Ordinarily they are placed directly in the middle of the ceiling whether or not that is the position most desirable from the standpoint of proper illumination of the room.

We will assume as a house for which we are going to design an electric lighting system, a country home having, on the first floor, a living room, a dining room, a kitchen, a front and a rear hall, a bed room and a large porch in front. On the second floor there are four bed-rooms, each provided with a closet, a bath room and a hall. In the cellar there is a large furnace room, a fuel room, a laundry, a vegetable room and a store room. Plans of the two floors and the basement are shown in Fig. (1*a*), (1*b*) and (1*c*).

Living Room.—Since this is the room in which most of the leisure time of the family is spent, it should be well lighted. First of all there must be a light for reading purposes. Since the family is likely to be large, several persons will often want to read at the same time, so a considerable area should be well enough illuminated to enable one to read anywhere within that area. When looking about for a lamp to furnish a light by which to read, the average person promptly selects a table reading lamp. The ordinary table electric reading lamp would be very satisfactory for one or possibly two persons to read by if a general illumination for the room were taken care of by other lamps.

In the ordinary farm home, however, usually more than one or two persons wish to read at the same time. Moreover, the lamp that furnishes light for reading is usually required to furnish a general illumination for the room. This a table lamp will not do. Accordingly, a three light fixture is provided as shown in Fig. 2.

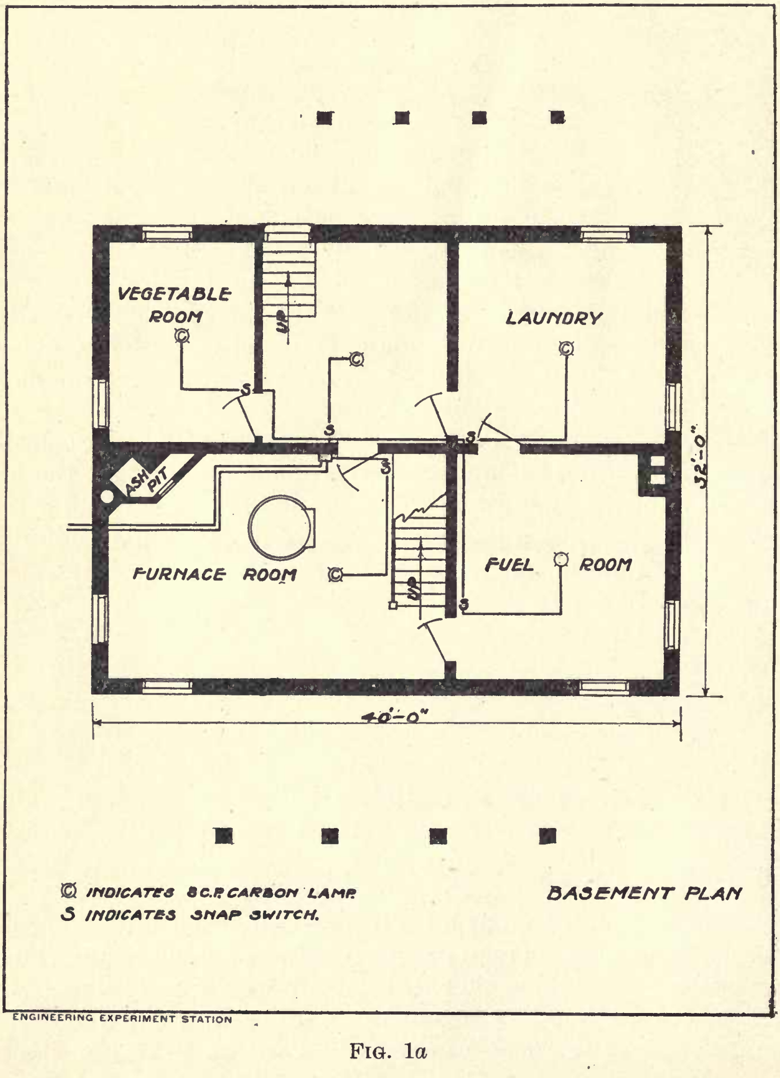
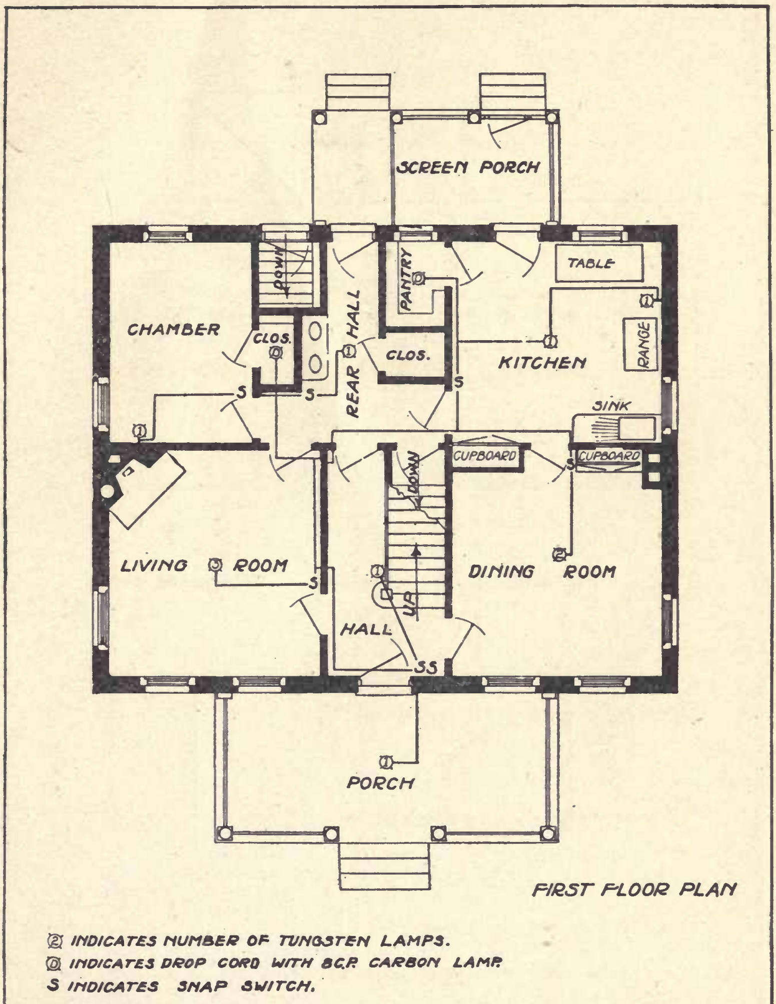


FIG. 1a



ENGINEERING EXPERIMENT STATION

Fig. 1b

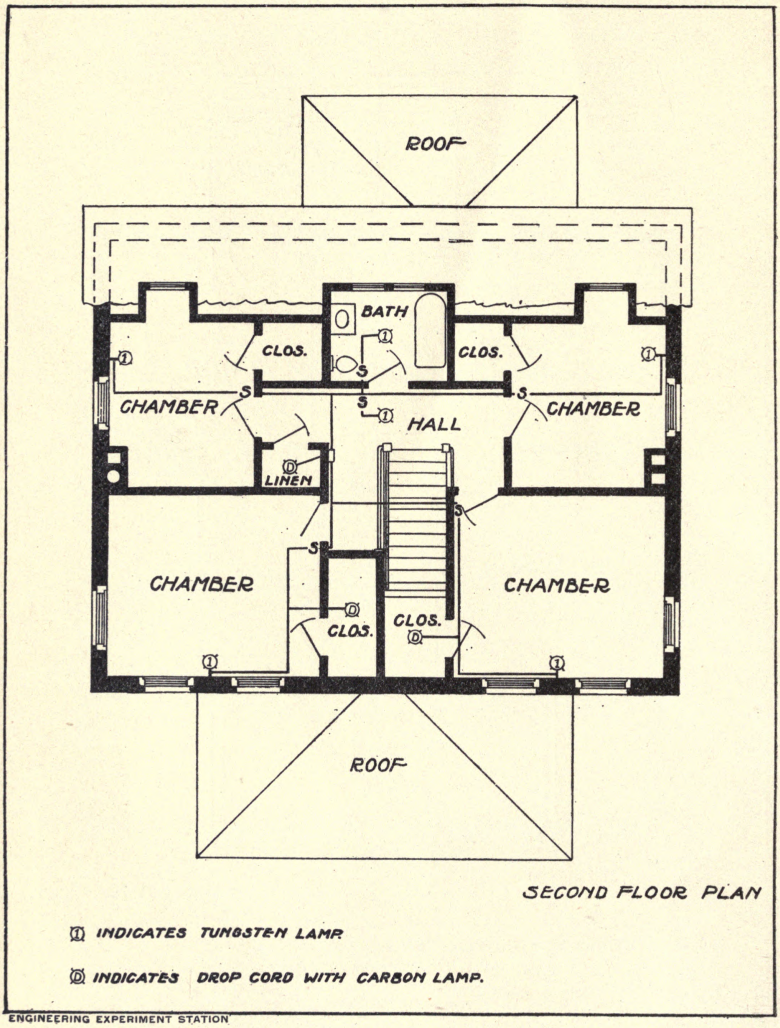

ROOF
BATH
CLOS.
CLOS.
CHAMBER
HALL
CHAMBER
LINEN
CHAMBER
CHAMBER
CLOS.
CLOS.
ROOF
SECOND FLOOR PLAN
Ⓣ INDICATES TUNGSTEN LAMP.
Ⓓ INDICATES DROP CORD WITH CARBON LAMP.
ENGINEERING EXPERIMENT STATION

FIG. 1c

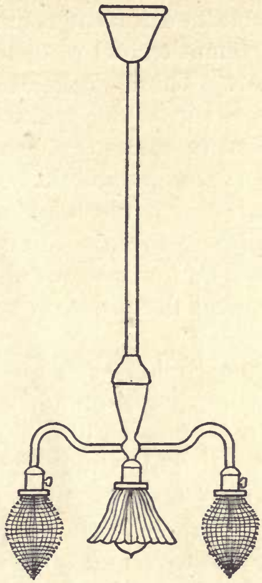


FIG. 2 LIVING ROOM FIXTURE

In this fixture the middle socket points directly downward, and is equipped with a prismatic glass reflector such as the Holophane, class B, "tulip" reflector. This will concentrate the light under the chandelier for reading purposes and at the same time permit sufficient light to pass through to give a moderate illumination of the walls and ceiling. Thus, the single reading lamp would be sufficient for ordinary occasions. On special occasions, however, when a general illumination rather than a concentrated light for reading is desired, the middle lamp is turned out and the two outside lamps are used. These two lamps are provided with prismatic reflecting globes of the shape shown. (Holophane, class B, stalactite). Since the reflecting globe will prevent the dazzling direct rays from the filament from reaching the eyes of a person in the room, the unfrosted lamps may be used. The middle lamp, however, may be seen from positions close under the chandelier. Hence a frosted lamp should be used here. The fixture should be hung so that the lamps are about six and one half feet from the floor.

Dining Room.—A dining room requires a strong illumination over the table and a soft pleasing light over the walls and

ceiling. This can be obtained for the room we are considering by two lamps placed in prismatic bowl reflectors hung at a height of six feet from the floor. These reflectors will distribute the light well to the edges of the table, while the ceiling and walls will be sufficiently lighted to make the room seem cheerful, but not brilliant. Frosted tip lamps should be used.

Front Hall.—A single unfrosted lamp placed in a Holophane, class B, stalactite, similar to the one shown in Fig. 2 will amply light the hall. It should be hung about eight feet from the floor so as to throw the strongest illumination toward the door and the foot of the stairs.

Kitchen.—The kitchen holds such an important place in the life of the farm house-wife that it should be well illuminated. It can be adequately lighted by a single lamp in a pendant fixture in the middle of the room. This should be provided with an opal bell reflector. The fixture is hung high so as to be out of the direct line of vision of a person in the room. To provide a more concentrated light over the stove and table where it is most needed there is an adjustable bracket fixture with an opal bell reflector and a frosted tip lamp. (Fig. 3.) This should be placed about six feet high and as nearly as possible between the stove and table. The lamp will be turned on only when needed and the light directed where desired by adjusting the bracket.

Front Porch.—One lamp placed inside of a prismatic reflecting ball similar to the one shown in Fig. 4 is used for lighting the porch. This is placed in front of the door and directly on the ceiling. The upper fluted portion of the ball throws the light downward where it is needed. The lower portion is frosted in order to soften the glare of the filament.

Cellar.—The lights in the cellar are equipped with the flat enameled metal reflectors. These are placed on the ceiling so as to distribute the light well over the walls and floor.

Bedrooms.—For each bedroom a bracket fixture carrying one light in an opal bell reflector is provided. This is placed high enough so that the dresser can be placed directly beneath it, thus furnishing a good light by which to dress. (Fig. 5.) This will also provide a sufficient general illumination if the lamp is inclined about 45° from the horizontal. The lamp should be frosted. An

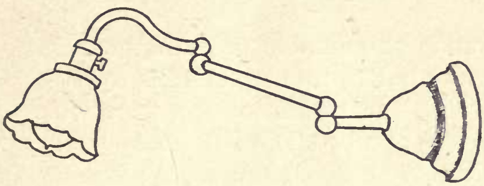


FIG. 3
ADJUSTABLE BRACKET FIXTURE

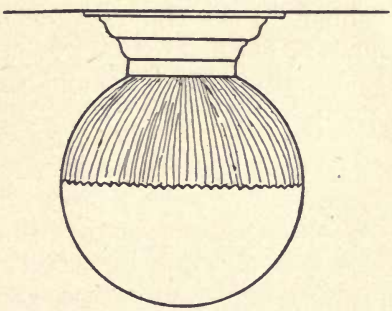


FIG. 4
REFLECTING BALL FOR VERANDA

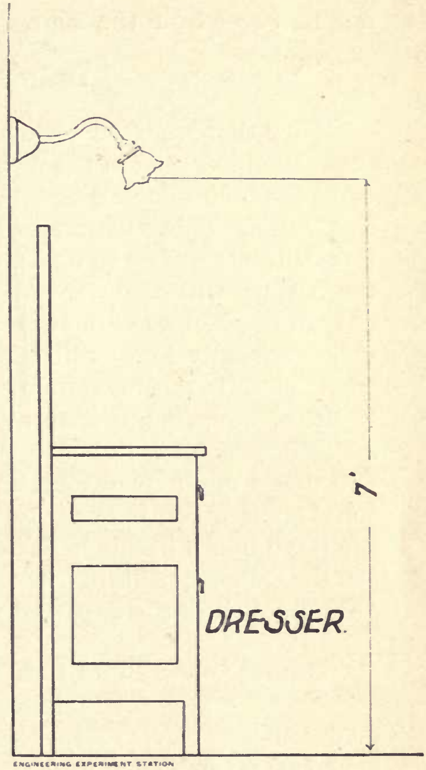


FIG. 5
SKETCH SHOWING GOOD LOCATION OF BEDROOM FIXTURE

eight candle power carbon lamp is placed in three of the closets. These are simple drop lights suspended about six and one half feet from the floor. No extra length of lamp cord should be provided, otherwise the lamp may be hung upon a hook in contact with some clothing. Then if the lamp is accidentally left lighted a fire is almost sure to occur.

Hall and Bath-room.—Simple, single light pendant fixtures are provided for the second floor hall and the bath room. These are

equipped with opal bell reflectors and are hung about seven and one half feet from the floor. The lamps should be frosted.

Design of Plant

Now that we have decided upon the number of lights in each room the next step in the design of our lighting system is to estimate the hours during the day that the lights in each room will be lighted. This will give us an idea of how large our storage battery will have to be to operate the lamps. Of course, the size of the battery will also depend upon how often it is convenient to charge it. Let us assume that we wish our battery to be of sufficient capacity to operate the lights on one charge, the entire day when there is the maximum amount of light used. This will be in the winter when the nights are long and when there is some special occasion that keeps the family up later than usual. We will make out a probable lighting schedule for this day. The schedule is given below. In the column to the right are given the lamp-hours per day. The lamp-hours per day for each room are the number of lights in that room multiplied by the number of hours during the day that they are lighted.

Dining Room: Two lights, on during breakfast and supper,

5:00–6:30 a. m. .... } 6 lamp hours
5:30–7:00 p. m. .... }

Living Room: Three lights, on only after supper,

7:00–10:30 p. m. .... 10½ lamp hours

Kitchen: Two lights, on while preparing meals and washing dishes, morning and evening,

5:00–7:30 a. m. .... } 10 lamp hours
5:00–7:30 p. m. .... }

Front Hall: One light

8:00–10:30 p. m. .... 2½ lamp hours

Front Porch: One light

7:30–9:00 p. m. .... 1½ lamp hours

Rear Hall:	One light	
5:00-6:00 a. m.		$2\frac{1}{2}$ lamp hours
6:00–7:30 p. m.		
Bedrooms:	Two lights	
5:00–5:30 a. m.		$2\frac{1}{2}$ lamp hours
9:00–9:30 p. m.		
	One light	
10:30–11:00 p. m.		
		$35\frac{1}{2}$ lamp hours

This gives a total of $35\frac{1}{2}$ lamp hours. Hence, we wish a battery that will operate one lamp approximately 36 hours, with one charge.

Before going further we must become familiar with another unit used in electrical measurements. It is called the ampere and is the unit by which we express current flow. We know that voltage is the electrical pressure or that which tends to make flow an electric current. When we say that a lamp is a 110 volt lamp we mean that it takes 110 volts of electrical pressure to drive sufficient current through the resistance of the lamp filament to heat it hot enough to glow. It does not, let us understand, indicate the amount of electricity that flows. It merely relates to the pressure that causes the current to flow. This current that flows through the filament or any other electrical conductor is measured in amperes. The lamps that we have chosen will allow about one ampere of current to flow through the filament when the pressure of 25 volts is applied, they being 25 volt lamps. We know that to produce continually a pressure of at least 25 volts, 15 storage cells are required. What we want to find out now is how large the cells must be to hold a sufficient charge to let one lamp burn for 36 hours. As we said before, one lamp will permit one ampere of current to flow. Hence the battery will have to be large enough to hold a charge such that one ampere can flow for 36 hours, that is to say, a 36 ampere-hour storage battery, the ampere-hour being the unit of capacity by which manufacturers rate storage batteries. The nearest commercial size of battery to 36 ampere hours is the 40 ampere hour battery. We will, therefore, choose that size of battery.

The "normal rate" of charging a storage battery is the number of amperes of current we must force into the battery to charge it in eight hours from an almost discharged condition. Since

ours is a 40 ampere-hour battery its normal charging rate is 40 divided by 8, or 5 amperes. When there is plenty of time for charging, it is best to charge the battery at the 5 ampere rate. However, if time is lacking it may be charged in a shorter time with a current of 7, 8 or even 9 amperes. This capacity of storage battery will require charging only once per day when there is the heaviest probable load. However, there will not ordinarily be as many lamps burning so many hours of the day, hence the battery will usually not require charging more than once in two days, even in winter. In the summer when the days are long and few lamps are necessary, one charge would be sufficient for a week or more.

Now that the battery is selected, we must decide upon the dynamo with which to charge it. Each cell of battery when fully charged will give a pressure of about 2.6 volts so that the entire 15 cells will give a pressure of 15 times 2.6, or 39 volts. Since in charging a battery the current must flow into the battery in a direction opposite to the flow of current when the battery is discharging, the entire voltage of the battery is opposing the voltage of the dynamo; i. e., the battery is connected to the dynamo so that it tries to drive current through the dynamo while the dynamo is driving its current at the same time into the same end of the storage battery. If then the dynamo is able to drive any current into the battery when it is almost charged, it must give a higher voltage than the maximum voltage of the battery. Since the maximum voltage of the battery is about 39 volts, then our dynamo should be able to generate about 42 or 43 volts. A 45 volt machine is a regular commercial size, so we will decide upon that voltage machine. The dynamo will have to be able to deliver a current equal to the greatest amount that will probably be used in charging the battery. When charging the battery in a short space of time 8 or 9 amperes may be used, so the current delivered by the dynamo must be at least this amount.

Dynamos are rated by the kilowatts of energy they will produce. As was explained before, a watt of electrical energy is equal to $\frac{1}{746}$ part of a horse-power. A kilowatt is equal to 1000 watts. Hence a kilowatt equals $\frac{1000}{746}$, or about 1.34 horse-power. Now the number of watts of electrical energy produced by a dynamo is equal to the product of the volts of pressure and the amperes of current. The dynamo we need must give at least 9

amperes of current at 45 volts pressure. Hence it must produce 9 times 45, or 405 watts. The nearest commercial size to 405 watts is the ½ kilowatt, or 500 watt size. Hence we shall decide upon a ½ kilowatt machine.

The gasoline engine to drive the dynamo must be able to produce 1.34 times as many horse-power as the dynamo does kilowatts, and besides enough to cover all losses in the dynamo. Since gasoline engines are usually rated rather high, and often on account of some lack of adjustment they do not give their full number of horse-power, it is well to get an engine considerably larger than the size calculated. For the ½ kilowatt dynamo, we should have a 2 horse-power engine.

A switchboard and apparatus with which to control the dynamo and storage battery are next to be selected. An adjustable resistance, called a rheostat, is supplied with the dynamo. This is to enable one to control the voltage of the dynamo so that the battery can be charged either rapidly or slowly. There must be an ammeter to measure the current that is being supplied the battery when charging; a voltmeter to measure the pressure produced by the machine, also that produced by the battery; and the voltage that is supplied the lamps. There should also be a circuit breaker, which is a sort of an automatic switch. Its purpose is as follows. Suppose that the battery is being charged by the dynamo and there is no attendant in the plant. If for any reason the engine stops, the dynamo of course fails to generate any voltage. Since the voltage of the storage battery is now no longer opposed by that of the dynamo, current will flow from the battery and tend to operate the dynamo as an electric motor. To prevent this action the circuit breaker is put in. As soon as for any reason the dynamo stops generating, the circuit breaker automatically opens the circuit and thus prevents current flowing from the battery to the dynamo.

As has been noted before, the storage battery when almost discharged gives only about 1.8 volts per cell, so that to produce the 25 volts necessary to light the lamps to full brilliancy, the entire 15 cells are required. However, when the cells have been fully charged and the charging current is stopped they give about 2.2 volts per cell, so that to light the lamps, all of the cells are not required. Hence a method should be provided to increase gradually the number of cells of battery that are being used, as

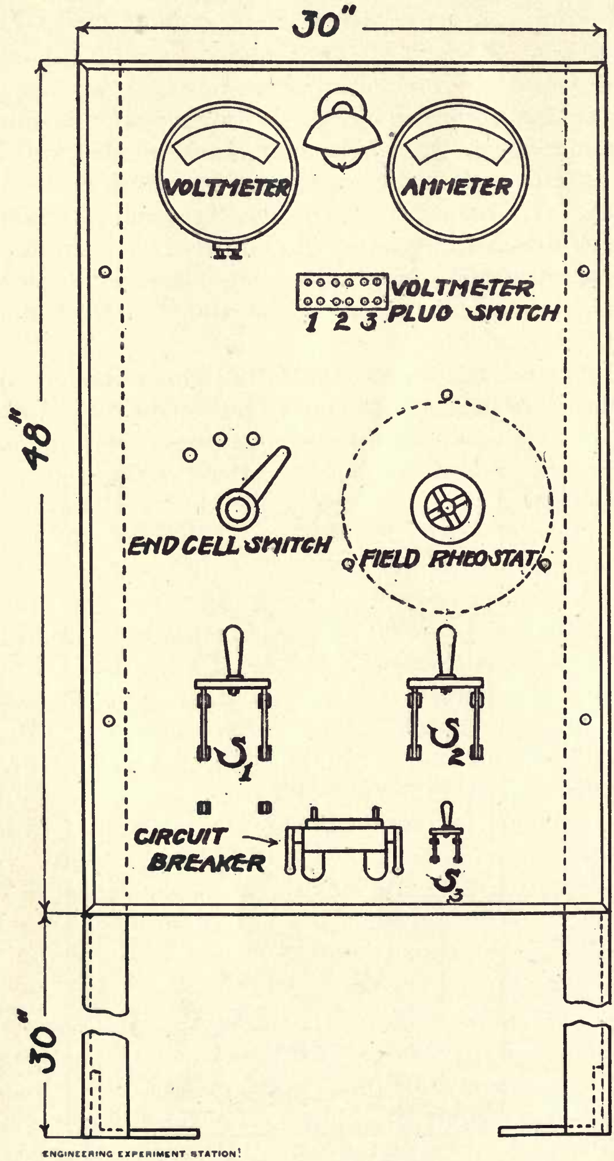


FIG. 6 FRONT VIEW OF SWITCH BOARD

the battery becomes more and more discharged. This will enable us to keep practically constant voltage supplied the lamps so that they will burn at almost their full brilliancy until the battery is discharged. For this purpose we provide an end cell switch.

Since we should be able to obtain a reading of the voltage at three different places and there is only one voltmeter, we must provide a way to switch the voltmeter terminals from one place to another. A plug switch is therefore provided, having three double pairs of holes, or jacks. To the upper pair of each one of these double pairs of jacks are connected the leads coming from the voltmeter. To the lower pair of the first double pair are brought leads from the two terminals of the dynamo; to the second, leads from the terminals of the battery; and to the third, leads from the two sides of the line leading to the lamps. By

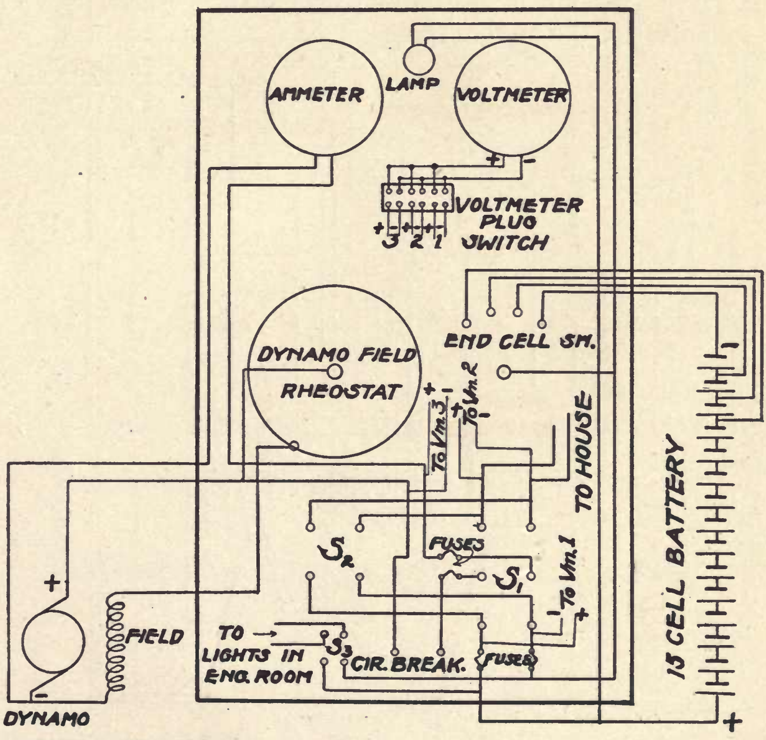


FIG. 7 SWITCH BOARD CONNECTIONS
Shown from Rear

means of a four point plug any one of the three pairs of leads can be switched on the voltmeter.

Two switches are provided,—one double throw switch by which we can throw the dynamo on to the battery for charging, or by throwing it the other way the lights can be operated directly from the generator. To operate the lamps directly from the dynamo, the voltage must be reduced to about 26 or 27 volts. Otherwise the lamps will soon be burned out by the excess voltage. By leaving this switch open and closing the other switch, the dynamo circuit is opened and the battery is operating the lights. Of course, by opening the latter switch also the lights are all turned off. Fig. 6 shows a diagram of the switchboard with the apparatus in place. Fig. 7 shows the rear of the board with the connections as they would be made. Fig. 8 shows a schematic diagram of the connections in the power plant. Fig. 9 shows the arrangement of the engine room.

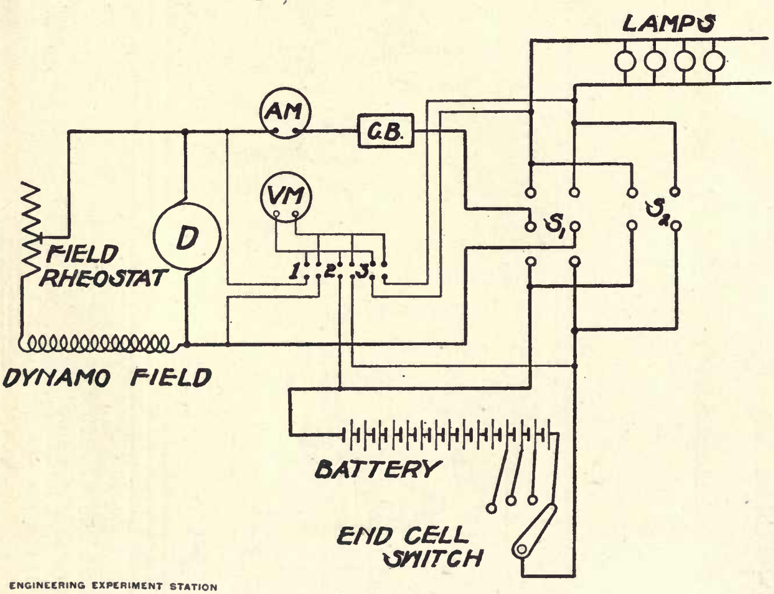


FIG. 8 WIRING DIAGRAM

AM—Ammeter
VM—Voltmeter
CB—Circuit Breaker
D—Dynamo
S_1, S_2—Switches
Light Lines are Voltmeter Leads

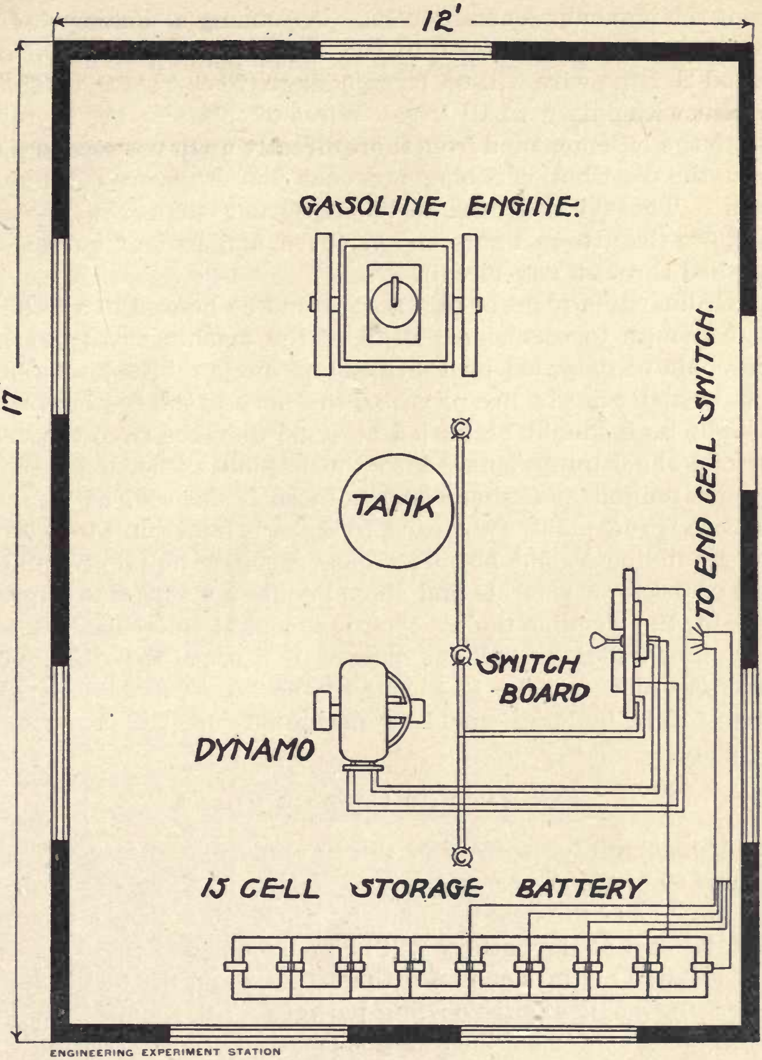


FIG. 9 ENGINE ROOM PLAN

All of the wires leading from the battery to the switchboard and the circuit from the switchboard to the armature terminals of the dynamo, and the one leading from the switchboard to the house should be large enough to carry the maximum current with only a small drop in voltage. For this case, 8 amperes will be

about the maximum current used. Assuming a distance of 200 feet from the switchboard to the cabinet in basement, No. 8 B. and S. gage wire will be large enough to carry the maximum current with only a small loss. Wires of this size are therefore run to the basement and from there directly up to the second floor. From the distribution cabinets on each floor leads are run to each room. These wires need to be no larger than No. 14 since not more than three lights, i. e., three amperes of current are supplied through any circuit.

Ordinarily a plant of this sort would be housed in a building large enough to accommodate all of the machinery of the farm that could be operated by the gasoline engine. Such a building would usually not be fire-proof, so to decrease the fire hazard the gasoline tank should be buried at some distance from the building and the supply pumped to the engine as needed. Where space is limited and where compactness is desired, as would be the case if the plant were used to light a house in town, a fire-proof building would be advisable. Such a building could be built of brick or concrete and should contain a separate compartment for the gasoline tank. The light plant could then be placed near other buildings without danger of fire. If the storage battery were placed in the basement of the house, as may be done, a 10 by 16 ft. building would be of ample size to accommodate the plant.

Estimate of Cost of Plant

A good storage battery of the 40 ampere-hour size will cost from $4.00 to $5.00 per cell. A quotation of $4.60 per cell was made by one of the best companies. Since 15 cells are required, the total cost of the battery will be approximately $70.00.

Gasoline engines can be estimated at about $60.00 per horse-power, the smallest sizes costing perhaps a little more than this. A two horse-power engine of a good make will cost about $125.00.

Complete switchboards vary in cost according to the material of the board, i. e., whether of slate or marble and according to the grade of the instruments and switches furnished. A first-class marble switchboard equipped with good instruments will cost approximately $100.00.

A one-half kilowatt dynamo, shunt wound, 45 volts, of a first-class make can be had for $65.00.

Seventeen tungsten lamps will be required, each costing $1.00, making a total of $17.00.

Fourteen 8 candle power, 25 volt carbon lamps will cost about $3.00.

1000 feet No. 14 wire	$12.00
550 feet No. 8 wire	25.00
Cabinet for basement	2.85
Cabinet for first floor	5.00
Cabinet for second floor	2.85
Porcelain cleats and tubes	2.00
18 snap switches	7.20
Labor: 2 men, 8 days, at $3.00	48.00

FIXTURES

Living Room: One 3 light pendant fixture fitted with one Holophane reflector and two stalactites	7.00
Dining Room: Two light fixtures with Holophane prismatic bowl reflectors	7.00
Front Hall: Single light fixture fitted with Holophane stalactite	4.00
Kitchen: Single light fixture fitted with opal bell reflector	2.00
One adjustable bracket fixture	2.00
Veranda: Prismatic reflecting ball in ceiling fixture	2.00
Cellar: Cleat receptacles	
Five required	1.25
Bedrooms: Single light bracket fixture with opal bell reflector	
Five required	6.25
Bath Room: Single light fixture with opal bell reflector	1.50
Hall: Second floor; Single light fixtures with opal bell reflector	1.50
Closet and Pantry: Five drop cords and sockets with ceiling rosettes	1.50

This makes a total cost of a little over $525.00 for the entire outfit and for its installation. Allowing for incidentals and for expenses unprovided for in the estimate the plant will cost not more than $550.00.

If necessary, the cost of several items of the estimate could be cut down so as to make a cheaper, though a very satisfactory installation. A 2 horse-power gasoline engine can be had on the

market for $100.00, that will serve our purpose. It will be lighter, will not run quite so steadily and will perhaps not last quite so long, but will do the work in a fairly good manner. The size and consequently the cost of the storage battery can be decreased if we are content to charge oftener. A 30 ampere-hour battery will cost about $1.00 less per cell than the 40 ampere-hour size. This will decrease the cost of the battery by $15.00. If one does not care so much for the appearance of the switchboard, a slate panel will do as well as a marble one and would be considerably cheaper. Less expensive instruments can be used so as to cut down the cost of the board to $80.00 or $90.00, thus decreasing the cost by about $15.00. The only method of cutting down the cost of the lighting fixtures that is recommended is to omit the lights in the closets, three of those in the basement and the light from the front porch. This would save about $5.00 in fixtures, wire, cleats and labor and $1.50 in lamps. A cabinet for each floor can be made by the wire men cheaper than the price given in the estimate. All three of them should not cost more than $5.00, decreasing the cost by $5.50. These changes will decrease the cost $78.50, making the plant cost a little more than $470.00.

For anyone who can afford a more expensive plant than the one we have designed there are several changes that can be made. In the apparatus of the engine room, i. e., the engine, battery, dynamo and switchboard there are not many changes that could be made to great advantage. A gasoline engine made especially for driving a dynamo can be bought at an increase of 25 per cent in the price quoted. These are much heavier than the one decided upon and will therefore run much more smoothly and give better satisfaction if lights are ever operated from the dynamo itself. A larger storage battery can be obtained if it is not desirable to charge often. The fixtures used in this design are very simple and inexpensive. If it is desired, much more elaborate and artistic ones can be bought. The dining room fixture may be a fancy art glass dome suspended by a chain. The others may be heavy cast-brass fixtures of any suitable design and costing almost any price that one is willing to pay. Any electric supply house will give quotations upon such fixtures.

Suggestions About Ordering Apparatus

Before ordering or asking for quotations upon any apparatus, the various steps of the design outlined in this bulletin

should be carried out as carefully as possible and the sizes of the various pieces estimated. Then in asking for quotations, for instance, on the storage battery, it should be stated about what size battery you think will be required. As a check upon the work it would be well to state to the company what size of house the plant is to light, how many lamps in each room and the maximum number of hours each lamp will burn per day. This will give the company information that will enable them to advise you as to the proper size of battery. To the company from whom quotations on the engine are asked it should be stated what size of dynamo it is intended to drive and what machinery, if any, will be operated by the engine at the same time that the dynamo is running and what machinery when the dynamo is not running. The company furnishing the dynamo should know that it is for battery charging, and just how many and what size cells are to be charged from it, and if it is desired to operate the lamps at any time directly from the dynamo. The storage battery companies are almost always in a position to furnish the switchboard and will fit it up according to the design given, if it is sent to them.

Operation and Care of Apparatus

Before attempting to use a plant such as the one just designed, full and complete instructions should be obtained from the various companies for the care and operation of the apparatus supplied by them. This is especially true of the engine and storage battery. All dynamos such as would be used for charging a battery are nearly enough alike so that instructions for the care of one dynamo would apply equally to all. However, gasoline engines and storage batteries differ enough so that explicit instructions should be obtained from the company furnishing them. Some instructions will be given here for the operation of the plant as a whole, for the care of the dynamo and some general directions as to the care and operation of the battery.

It is presumed that a competent person will be obtained to install the apparatus and do the wiring. Such a person can be found in almost any small city, and it will be more satisfactory to employ him than for a novice to attempt to do the work. However, it is seldom that even a man who is perfectly competent to install the machines and do the wiring, knows much about storage batteries. It would be well then to insist, however competent

the man is known to be, that he follow the general directions which will be given regarding the installing and preliminary treatment of the storage batteries.

For the proper operation of the storage battery there will be needed two small pieces of apparatus. One is a hydrometer, which is a small glass instrument similar in appearance to a thermometer. Its purpose is to determine the density of the solution or the electrolyte in which the plates of the battery are immersed. To use one of these hydrometers, all that must be done is to place it in the solution between the plates of the cell, taking care that it floats free of the plates. It will sink so that more or less of its stem is immersed in the liquid. This stem has a graduated scale and the reading taken at the surface of the liquid gives the density, or specific gravity of the electrolyte, that is to say, how many times heavier it is than pure water. The company from whom the battery is bought will furnish one of these hydrometers for about $1.00 or $1.25. There will also be needed a small portable voltmeter that will measure up to three volts. This is used for determining the voltage of each individual cell. A suitable instrument of this kind may be had from almost any electrical supply house at prices varying from $4.00 to $10.00.

The engine, generator and switchboard should be installed, tested and ready to operate before the storage battery arrives. As soon as the cells arrive they should be unpacked and assembled according to the directions furnished by the company. A strong set of shelves should be built upon which to place the battery, and it should be remembered in building them that nails and bolts are soon corroded and weakened by the acid fumes. These shelves should be arranged so that there is plenty of room around the battery so that the plates can be examined and the voltage and the density of the electrolyte tested. If the cells are placed in two rows, one on top of the other, there should be a space of at least one foot between the top of the lower cell and the bottom of the top shelf. Wooden sand trays and insulators are usually supplied by the company furnishing the battery. Each of these trays is filled with sand and placed upon four of the insulators. The battery jar is then set upon the sand, adjusted so that it is level and has a bearing over the entire bottom. The cells are connected so that the positive plate of one cell is connected to the negative plate of the next through the entire battery. Great

care must be taken to connect the positive plate of the first cell of the battery to the positive terminal of the dynamo. The positive plate of the battery can be distinguished by its dark brown color. The negative has a sort of a yellowish gray color. The positive terminal of the dynamo can be found by tracing back from the switchboard voltmeter. Have the dynamo running and connect the voltmeter to the dynamo terminals so that it reads in the proper direction. Then trace from the voltmeter terminal marked + back to the dynamo. The terminal to which it is traced will be the positive one. Care should be taken that this terminal leads to the end of the battery having the first plate of a brown color.

The acid solution, or electrolyte, should in no case be put into the jars until every thing is ready to begin charging the battery. When all is ready the solution is put in, the engine and dynamo started up, and the rheostat adjusted until the proper charging current is indicated upon the ammeter. As a precautionary measure, it is well before closing the switch to the battery, to adjust the rheostat until the voltmeter reads about 30 volts. Then the switch is closed and the rheostat adjusted until the battery is charging at its 10 hour rate. In the case of the 40 ampere-hour battery, this would be approximately 4 amperes. The electrolyte, which should be obtained ready mixed from the battery company, should show a specific gravity of about 1.17 at the beginning of the charge. The charging should be continued for 10 hours a day for about three days, or until the electrolyte bubbles freely. The specific gravity of the solution and the voltage of the cells will then have reached stationary values of about 1.2 specific gravity and 2.5 volts. During this charge the current should be kept at a constant value of about 4 amperes by the adjustment of the rheostat. The battery may now be used for lighting until discharged down to about 2.00 volts per cell, after which it should be given another thorough charge. This system of moderate discharge and thorough charge should be kept up for two or three cycles of charge and discharge, after which the battery should be in a first-class condition. These are general instructions for almost any type of battery. If explicit instructions for the preliminary treatment of the battery are furnished by the storage battery company, they should be

followed closely instead of the directions given above. The ones given here are for use in case other instructions are lacking.

After the preliminary treatment of the cells, the battery may be charged at any convenient time no matter whether fully discharged or not. If a large engine has been purchased with the idea of operating other machinery at the same time that the dynamo is running, the dynamo may be started and the battery put on charge whenever the other machinery has to be used. Suppose we had decided upon a 3 horse-power engine with the idea in mind of operating a feed grinder at the same time as the dynamo. Then whenever the grinder has to be used it would pay to start the dynamo and charge the battery whether or not it had been discharged down to 1.9 or 2.00 volts per cell.

There are two things that must always be borne in mind in operating the storage battery. The first is that the cells must not under any circumstances be discharged below 1.8 volts per cell and preferably not below 1.9 or 1.95 volts. If discharged to a too low voltage a harmful white sulphate forms upon the lead plates. This sulphate always forms when the plates are being discharged, but if the discharge is not carried too far it is destroyed or reduced when they are charged again. The abnormal sulphate caused by a too low discharge is almost impossible to reduce and it causes the plates to bend or buckle, increases the resistance of the battery and consequently lowers its efficiency and decreases the ampere-hour capacity of the battery. The other precaution is to be sure that the battery gets a thorough charge up to 2.5 or 2.6 volts per cell every week or so. This will reduce the sulphate that has been formed on discharge and will keep the cells in good condition.

The voltage and the density, or specific gravity of the electrolyte of each cell, should be observed at least every two weeks and the battery company notified and asked for advice if either seems to show unusual values. As has been noted before, the voltage per cell should vary from 1.8 volts at the lowest allowable discharge to about 2.6 volts in the fully charged condition dropping to 2.2 or 2.3 volts when the charging current is stopped. The specific gravity should not fall below about 1.18 when discharged nor above 1.24 when fully charged. If the batteries are well cared for the density will usually remain about correct, if they are periodically filled up with pure water to supply the loss

by evaporation. It is best to use nothing but distilled water for the cells, but if no distilled water can be obtained, good, pure filtered rain water may be used.

The battery should be charging at its "normal" rate when filling up the cells with water to make good the losses by evaporation. This causes the water to mix more quickly with the electrolyte and prevents the harmful results caused by having the electrolyte of non-uniform density.

The battery should not be allowed to stand idle after discharge has taken place. Put it on charge as soon as possible after it has reached a voltage of about 1.9 volts per cell.

Sediment should not be permitted to collect in the bottom of the battery jars. If it does collect the cell should be fully charged, removed from the battery, the electrolyte drawn out and the sediment removed.

The color of the plates should be carefully watched, as their color gives a good indication of their condition. When the plates are first set up the negatives are a yellowish gray and the positives dark brown, usually spotted with whitish or reddish gray substances. The spots are sulphate and should disappear when the cell is fully charged. When in good operating condition the positives are dark red, chocolate or plum color, becoming nearly black when charged. If fully discharged, the whitish or reddish gray patches of sulphate appear. The negatives are a sort of a pale slate color that becomes darker as the plates are charged. When the plates are in good condition the surface of the positive plates is soft and the color will rub off on the finger. When in bad condition the surface is usually hard.

Voltmeter reading of the cells should be taken while the battery is discharging in order to get a good idea of the true condition of the cells. Often a cell, when standing idle, will indicate a voltage of perhaps 2.0 volts, but as soon as any current is taken from it, the reading will immediately drop to a much lower value.

The engine room should be heated in the winter to keep the solution from freezing. A low temperature of the electrolyte decreases the capacity of the battery to a marked extent. Hence if the battery is to produce its full rated number of ampere-hours in the winter, the room should be kept at a temperature of not less than 55° or 60° Fahrenheit. In many cases it might be well to have the battery in the cellar of the house. Then the

solution would keep from freezing without the aid of artificial heat. This will, of course, necessitate having the wires to the storage battery much longer than we have estimated. Hence the cost of the wire will be increased somewhat, but the increased cost would probably be justified.

The principal things to watch about the dynamo are the bearings, the commutator and the brushes. Needless to say, the bearings should always be kept supplied with a good quality of oil, and watched to see that the oiling rings rotate freely when the machine is running. The brushes and commutator should be watched carefully. If there is sparking at the brushes they should be examined to see if they fit the commutator perfectly at every point. If not, they should be sandpapered carefully as follows. Take a strip of extra fine sand paper (never emery cloth) a trifle narrower than the commutator is long. Lift up the brush and slip the paper under it with the smooth side next the commutator. Then after letting the brush down and holding the paper snugly against the commutator, carefully draw the paper under the brush in the direction in which the commutator turns when the dynamo is in operation. Lift the brush, remove the paper and repeat the process until the brush fits perfectly. When the commutator is in good condition it will not have a bright metallic copper color, but will have a fine dark luster. If the commutator is bright after operating for a while the brushes probably bear too hard or else there has been sparking at the brushes. Occasionally the commutator should be cleaned by holding a soft rag, slightly oily, upon the commutator while the machine is running. This will lubricate the surface slightly and tend to make the brushes operate smoothly.

Cost of Operation

The principal cost of running a plant such as the one designed is the cost of operating a gasoline engine. A two horse-power engine will cost about 5 cents per hour for gasoline running at full load. When the engine is driving the dynamo alone it is giving about .7 horse-power and the cost of gasoline is about 1.8 cents per hour. These figures are assuming gasoline at 18 cents per gallon. The dynamo costs very little to operate; almost the only item is that of oil for the bearings; this is, of course, small. The storage battery requires no supplies except that occasionally

some sulphuric acid will have to be added to the electrolyte of those cells whose specific gravity has fallen low. The acid costs only about 5 or 6 cents a pound and only a small quantity is needed so this item is almost negligible. Depreciation is the most important item in storage battery operation and this depends altogether upon the treatment of the battery. It matters not how good or how poor a cell may be, careless treatment will reduce its life of useful service to a few months. The cost of maintenance or making good this depreciation is practically that of renewing the plates. With careful use the positive plates of a battery such as has been selected for this design will probably need renewal in 4 or 5 years and the negatives in 8 or 10 years. This will make the average annual cost of maintaining the battery $8.00 or $10.00 per year.

Glossary of Technical Terms

Acid Solution. The mixture of sulphuric acid and distilled water in which the plates of the storage battery are immersed.

Ammeter. An instrument for measuring the amount in amperes of electric current flowing in the circuit.

Ampere. The unit of current flow in electricity. It is the current that will flow when a pressure of 1 volt is applied to a circuit having a resistance of 1 ohm.

Ampere-Hour. The number of amperes flowing in a circuit multiplied by the number of hours that it flows.

Armature. That part of the dynamo in which the voltage is generated. Usually the rotating part of the dynamo.

Bracket Fixture. A lighting fixture which is fastened to the wall in the manner of a bracket. See Fig. 3.

Brilliancy of Illumination. The brightness or intensity of illumination. It depends upon the candle power and the distance of the surface illuminated from the light giving source.

Brushes. The small carbon blocks on a dynamo which collect the current from the rotating commutator.

Cabinet. A box or cabinet from which is made the distribution of wires to the different rooms on each floor.

Capacity. (Of battery). The number of ampere-hours of charge the storage battery is designed to receive. (Of dynamo). The number of kilowatts the dynamo is designed to

generate. (Of engine). The number of horse-power the engine is designed to produce.

Ceiling Rosette. A device made of porcelain by means of which connections are made from a drop cord through the ceiling to the wires above.

Cell. One complete unit of a storage battery consisting of jar, plates, electrolyte, sand tray and insulators.

Circuit Breaker. An automatic switch for opening battery charging circuit when for any reason, the dynamo fails to deliver current.

Cleat. A small porcelain device for fastening and insulating current carrying wires.

Cleat Receptacle. A combination of a cleat and receptacle for holding an incandescent lamp.

Commutator. The rotating segmented copper portion of the dynamo from which the current is collected by means of the brushes.

Conductor. Any substance which allows electric current to flow through it. The insulated wire which is used to carry the current.

Current. The amount of electricity that flows. It is measured in amperes.

Density of Electrolyte. The specific gravity of the electrolyte. The number of times a given quantity of electrolyte is heavier than the same quantity of pure water.

Diffusing Globe. A globe that breaks the light up into fine rays, thus softening it to the eyes and removing the dazzling and glaring effect of the light.

Diffusion. The process of breaking the light up into fine rays, as by means of a diffusing globe.

Distilled Water. Water that has been condensed from steam.

Double Throw Switch. A switch arranged so as to enable one to throw either of two pairs of wires into circuit. See "S" in Fig. 6.

Drop Cord. A pair of flexible rubber insulated wires fitted with a lamp socket. They are used where a very cheap sort of a lighting fixture is desired.

Dynamo. A machine for generating electrical power.

Electrolyte. The acid solution. A mixture of sulphuric acid and water in which the plates of the storage battery are immersed.

End Cell. A cell of storage battery which is arranged so that it can be cut into or out of the circuit, so as to regulate the voltage of the battery.

End Cell Switch. The switch by means of which the end cells are cut into or out of the circuit.

Fahrenheit. The scale into which the thermometers ordinarily in use are divided.

Filament. The light-giving part of an incandescent electric lamp.

Generator. A machine for generating electrical power. A dynamo.

Holophane Globe or Shade. A globe or shade made by the Holophane Glass Co. They are made of clear glass, but have flutings or prisms that deflect and diffuse the light.

Horse-Power. The unit of mechanical power. It requires one horse-power to raise 33,000 pounds one foot high in one minute or the equivalent. A horse-power equals 746 watts of electrical power.

Hydrometer. An instrument for measuring the density of specific gravity of a liquid.

Incandescent Electric Lamp. An electric lamp in which a conducting filament is heated by an electric current to a temperature sufficiently high to give off light.

Insulator. A substance that will not permit the passage of an electric current. A sort of glass knob used to insulate the storage battery from the ground.

Intensity of Light. The number of candle power of light produced by a lamp divided by the area of the light-giving source, i. e., in an electric lamp, the area of the filament.

Kilowatt. Equal to 1000 watts or 1.34 horse-power.

Lamp Cord. A flexible, twisted, two conductor wire used in making drop and extension cords.

Lamp-Hours. The number of lamps multiplied by the number of hours during which they burn.

Negative Plate. The grayish colored plate of the storage battery.

Negative Terminal. The terminal of the dynamo or battery to which the current returns after passing through the circuit.

Normal Rate of Charge. The number of amperes which must be forced into a battery to charge it in 8 hours from a nearly discharged condition.

Pendant Fixture. A lighting fixture which is hung from the ceiling. See Fig. 2.

Plug Switch. A switch in which electrical connection is made by placing a metallic plug into a metallic jack or hole.

Positive Plate. The brown or chocolate-colored plate of a storage battery.

Positive Terminal. The terminal of a dynamo or battery from which the current flows to the circuit.

Pressure. Voltage. That which tends to cause an electric current to flow.

Prismatic Reflecting Globes. Globes made of clear glass which diffuse and reflect the light by means of prisms and flutings on the surface.

Resistance. The opposition any conductor presents to the flow of an electric current. It is measured in ohms. 1000 feet of copper wire .1 of an inch in diameter has a resistance of 1 ohm.

Rheostat. An adjustable resistance used for varying the current in a circuit.

Snap Switch. A small spring switch operated by turning a small button or key.

Socket. A device for holding and making electrical connection to the filament of an incandescent lamp.

Specific Gravity. Density. The number of times any substance is heavier than pure water.

Storage Battery. An apparatus consisting of prepared lead plates immersed in dilute sulphuric acid by means of which electric power is stored.

Sulphate. A white substance that sometimes forms on the plates of a storage battery.

Sulphuric Acid. The acid whose chemical formula is H_2SO_4. It is used diluted as the electrolyte for a storage battery.

Switchboard. The slate or marble panel upon which measuring instruments, controlling switches, rheostat, etc., necessary for the operation of the plant, are mounted.

Tubes. Cylindrical tubes made of porcelain; used for insulating a current-carrying wire where it passes through a hole in the wall, partition, etc.

Tungsten Filament. A filament for an incandescent lamp made from the rare metal, tungsten.

Volt. The unit of electrical pressure or voltage. It is equal to about half the pressure produced by an ordinary dry battery.

Voltage. Difference of electrical pressure or that which tends to make current flow.

Voltmeter. An instrument for measuring voltage.

Watt. The unit of electrical power. Equal to $\frac{1}{746}$ part of a horse-power. Watts equal volts times amperes.

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Circular No. 1. High-Speed Tool Steels, by L. P. Breckenridge. 1905.

Bulletin No. 2. Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and Henry B. Dirks. 1905.

Circular No. 2. Drainage of Earth Roads, by Ira O. Baker. 1906. (*Out of print.*)

Bulletin No. 3. The Engineering Experiment Station of the University of Illinois, by L. P. Breckenridge. 1906. (*Out of print.*)

Bulletin No. 4. Tests of Reinforced Concrete Beams, Series of 1905, by Arthur N. Talbot. 1906.

Bulletin No. 5. Resistance of Tubes to Collapse, by Albert P. Carman. 1906. (*Out of print.*)

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